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STEP STRESS TESTING PROGRAM

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FINAL REPORT
FOR

JANTX2N2219A

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For

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FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.

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1.0 INTRODUCTION

DCA Reliability Laboratory, under Contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the dual transistor JANTX-2N2219A manufactured by Texas Instruments and National Semiconductor.

A total of 48 samples from each manufacturer were submitted to the process outlined in Table 1. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 high-speed computer-controlled tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit shown in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The current was set by I_E and the voltage was varied to comply with the specified power rating for this device. At least one of the devices was subjected to maximum rated power (MRP). All remaining devices

were subjected to no less than 90% of MRP. See Figure 1 for load resistance values and voltages.

2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the Power Stress Process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150, and 175 percent of MRP for 2500 hours or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1. (*See Notes at end of text.)

2.4 Group II - Temperature Stress I

Thirty-one units, 16 from each manufacturer, were submitted to the Temperature Stress I Process. Group II was subjected to 1600 hours of stress at MRP in increments of 160 hours. The temperature was increased in steps of 25°C, commencing at 75°C and terminating at 300°C or until 50% or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II Process. Group III was subjected to 112 hours of stress at MRP in increments of 16 hours. The temperature was increased in steps of 25°C, commencing at 150°C and terminating at 300°C or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified

electrical parameters after each temperature step. See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 Texas Instruments. The Texas Instruments sample lot completed the entire 2500-hour Group I Testing with two catastrophic failures. The first failure occurred 25 hours into the 125% MRP step. Serial number 4610 failed the maximum h_{FE} limit. Serial number 4603 was removed from the testing 10 hours into the 175% MRP step as a MIL-S-19500 failure. The last failure occurred 500 hours into the 1750% MRP step. Serial number 4613 failed the maximum I_{CBO}, $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ limits. Typical characteristics of this sample lot's performance were:

1) The mean value for I_{CBO} changed 713.6μA from an initial mean of 397.5pA to a final mean of 713.6μA.
2) The mean value for $V_{CE(SAT)1}$ changed 750.5mV from an initial mean of 117.8mV to a final mean of 868.3mV.
3) The mean value for $V_{CE(SAT)2}$ changed 849.6mV from an initial mean of 301.4mV to a final mean of 1.151V.
4) The mean value for h_{FE} changed 84.20 from an initial mean of 165.1 to a final mean of 246.3.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.2 National Semiconductor. The National Semiconductor sample lot completed 2000 hours of Group I Testing, at which point 50% of the lot failed. The lot was processed an additional 10 hours and had three more catastrophic failures. The first failure occurred 25 hours into the 125% MRP step. Serial number 4661 failed the minimum h_{FE} limit. The next failures occurred 50 hours into the 150% MRP step. Serial numbers 4657, 4663 and 4665 failed the minimum h_{FE} limit. The next failures occurred 500 hours into the 150% MRP step. Serial numbers 4650, 4652 and 4662 failed the minimum h_{FE} limit. The last failures occurred 10 hours into the 175% MRP step. Serial number 4649 failed the maximum h_{FE} limit. Serial numbers 4651 and 4653 failed the minimum h_{FE} and maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ limits. Typical characteristics of this lot's performance were:

1) The mean value for I_{CBO} changed 1.110mA from an initial mean of 1.301nA to a final mean of 1.110mA.
2) The mean value for $V_{CE(SAT)1}$ changed 2.200V from an initial mean of 133.0mV to a final mean of 2.333V.
3) The mean value for $V_{CE(SAT)2}$ changed 2.183V from an initial mean of 311.4V to a final mean of 2.494V.
4) The mean value for h_{FE} changed 24.20 from an initial mean of 201.1 to a final mean of 225.3.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.3 Statistical Summary - Group I. Table 4 outlines

the results of Group I - Power Stress Process for each of the four electrical parameters and all measurement points for both Texas Instruments and National Semiconductor.

3.2 Group II - Temperature Stress I

3.2.1 Texas Instruments. The Texas Instruments sample lot completed 960 hours of Group II Testing before it was stopped because more than 50% of the devices failed. The first failure occurred 160 hours into the 75°C-temperature step. Serial number 4627 failed due to excessive I_R leakage. The next failures occurred 160 hours into the 125°C-temperature step. Serial number 4621 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. The next failures occurred 160 hours into the 150°C-temperature step. Serial number 4624 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. Serial number 4629 failed due to excessive I_{CBO} leakage. The next failures occurred 160 hours into the 175°C-temperature step. Serial number 4628 failed due to excessive I_{CBO} leakage. Serial number 4630 failed the minimum h_{FE} limit. The last failures occurred 160 hours into the 200°C-temperature step. Serial number 4616 failed due to excessive I_{CBO} leakage. Serial numbers 4619 and 4623 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. Typical characteristics of this lot's performance were:

1) The mean value for I_{CBO} changed 1.216mA from an initial mean of 444.4pA to a final mean of 1.216mA.

2) The mean value for $V_{CE(SAT)}1$ changed 1.988V from an initial mean of 115.1mV to a final mean of 2.103V.

3) The mean value for $V_{CE(SAT)}2$ changed 1.975V from an initial mean of 300.3mV to a final mean of 2.275V.

4) The mean value for h_{FE} changed 8.300 from an initial mean of 210.5 to a final mean of 218.8.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.2 National Semiconductor. The National Semiconductor lot completed 966 hours of Group II Testing before being stopped because more than 50% of the devices failed. The first failure occurred 160 hours into the 75°C-temperature step. Serial number 4673 failed the maximum h_{FE} step. The next failures occurred 160 hours into the 125°C-temperature step. Serial numbers 4666 and 4672 failed the minimum h_{FE} limit. The next failures occurred 160 hours into the 150°C-temperature step. Serial number 4677 failed the maximum I_{CbO}, $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$ limits. Serial number 4679 failed the maximum I_{CBO} and minimum h_{FE} limits. The next failures occurred 160 hours into the 175°C-temperature step. Serial numbers 4670 and 4676 failed the minimum h_{FE} limit. The last failures occurred 160 hours into the 200°C-temperature step. Serial numbers 4668, 4669 and 4675 failed the minimum h_{FE} limit. Typical characteristics of this lot's performance were:

1) The mean value for I_{CBO} changed 1.585mA from an initial mean of 1.686nA to

a final mean of 3.271nA.

2) The mean value for $V_{CE(SAT)1}$ changed 32.00mV from an initial mean of 144.3mV to a final mean of 176.3mV.

3) The mean value for $V_{CE(SAT)2}$ changed 123.7mV from an initial mean of 359.9mV to a final mean of 483.6mV.

4) The mean value for h_{FE} changed 106.1 from an initial mean of 214.6 to a final mean of 108.5.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.3 Statistical Summary - Group II. Table 5 outlines the results of Group II - Temperature Stress I Testing for each of the four electrical parameters and all measurement points for both Texas Instruments and National Semiconductor.

3.3 Group III - Temperature Stress I

3.3.1 Texas Instruments. The Texas Instruments sample lot completed the entire 112 hours of Group III Testing with a total of 13 catastrophic failures. The first failure occurred 16 hours into the 250°C-temperature step. Serial number 4641 failed the minimum h_{FE} limits. The next failures occurred 16 hours into the 275°C-temperature step. Serial numbers 4637, 4645 and 4646 failed the maximum $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. Serial number 4644 failed the maximum I_{CBO}, $V_{CE(SAT)1}$ and $V_{CE(SAT)2}$ and minimum h_{FE} limits. The last failures occurred 16 hours into the 300°C-temperature step. Serial number 4642 failed

due to excessive I_{CBO} leakage. Serial numbers 4632 and 4643 failed the maximum $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$ and minimum h_{FE} limits. Serial numbers 4631, 4634, 4636, 4639 and 4640 failed the maximum I_{CBO}, $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$, and minimum h_{FE} limits. Serial number 4633 was removed as a visual reject due to handling. Typical characteristics of this lot's performance were:

1) The mean value for I_{CBO} changed 599.0nA from an initial mean of 610.6pA to a final mean of 599.6nA.
2) The mean value for $V_{CE(SAT)}1$ changed 6.943V from an initial mean of 116.9mV to a final mean of 7.060V.
3) The mean value for $V_{CE(SAT)}2$ changed 6.881V from an initial mean of 290.0mV to a final mean of 7.171V.
4) The mean value for h_{FE} changed 77.90 from an initial mean of 217.4 to a final mean of 139.5.

The control units for this sample lot remained constant throughout the entire Group III Testing.

3.3.2 National Semiconductor. The National Semiconductor sample lot completed the entire 112 hours of Group II Testing with 10 catastrophic failures. The first failures occurred 16 hours into the 200°C-temperature step. Serial numbers 4684 and 4697 failed the minimum h_{FE} limits. The next failures occurred 16 hours into the 225°C-temperature step. Serial numbers 4689 and 4695 failed because of excessive I_{CBO} leakage. The next failure occurred 16 hours into the 250°C-temperature step. Serial number 4694 failed due to

excessive I_{CBO} leakage. The next failures occurred 16 hours into the 275°C-temperature step. Serial number 4685 failed the maximum I_{CBO}, $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$ and minimum h_{FE} limits. Serial number 4690 failed the maximum I_{CBO}, $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$ limits. The last failures occurred 16 hours into the 300°C-temperature step. Serial number 4682 failed due to excessive I_{CBO} leakage. Serial numbers 4686 and 4691 failed the maximum I_{CBO}, $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$. Serial number 4692 failed the maximum h_{FE} limit. Serial number 4696 failed the maximum $V_{CE(SAT)}1$ and $V_{CE(SAT)}2$ and minimum h_{FE} limits. Typical characteristics of this lot's characteristics were:

1) The mean value for I_{CBO} changed 384.9nA from an initial mean of 1.442nA to a final mean of 386.3nA.
2) The mean value for $V_{CE(SAT)}1$ changed 3.328V from an initial mean of 142.1mV to a final mean of 3.470V.
3) The mean value for $V_{CE(SAT)}2$ changed 3.393V from an initial mean of 331.8mV to a final mean of 3.725V.
4) The mean value for h_{FE} changed 205.3 from an initial mean of 226.7 to a final mean of 432.0.

The control units for this group remained constant for the entire Group III Testing.

3.3.3 Statistical Summary - Group II. Table 6 outlines the results of Group III - Temperature Stress II Testing, for each of the four electrical parameters and all measurement points for both Texas Instruments and National Semiconductor.

4.0 FINAL DATA SUMMARY

Table 7 statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables 8 and 9 summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table 8 and parametric failures in Table 9. The data from Table 8 were used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in 3 and 5 respectively. Junction temperature is plotted on an inverse hyperolic scale.

5.0 CONCLUSIONS

Taking all three stress groups into consideration, the Texas Instruments device proved to be the higher quality device. In the Group I Testing the Texas Instruments sample lot developed two catastrophic failures in 2500 hours of testing, whereas the National Semiconductor sample lot had to be stopped 450 hours before the end of the testing. Although Texas Instruments developed one more catastrophic failure than National Semiconductor during the Group III Testing, note that four failures occurred in the National Semiconductor sample lot before Texas Instruments had their

first.

The Group II Testing failure analysis points out that many Texas Instruments parts have clumps of silicon material scattered over the dice. Gold-aluminum intermetallic contamination can also be seen on many of the Texas Instruments devices. The National Semiconductor's parts showed no consistent failure mode, although like the Texas Instruments sample lot, many of the National Semiconductor parts showed signs of gold-aluminum intermetallic contamination.

A plot showing cumulative failure distribution for Groups II and III was drawn for Texas Instruments and National Semiconductor sample lots (Figures 2 and 3, and 4 and 5 respectively). Figures 2 and 3 display the data for the Texas Instruments sample lot used to calculate an activation energy of .579eV. Figures 4 and 5 display the data for the National Semiconductor sample lot used to calculate an activation energy of .797eV.

A broken circle around a marked point denotes a freak failure not calculated as part of the regression line. A solid circle around a marked point denotes an isolated failure point. The regression line was drawn using the least square method.

In Figure 2, Texas Instruments, the Group III failures at 300°C were not calculated into the regression line because of the common failure mechanism of gold-aluminum intermetallic contamination.

The activation energy was calculated from the formula:

$$E = \left[\ell n \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^{\circ}\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{eV}$$

Where: t_1 = step of Group II - Temp Stress I = 60 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^{\circ}$C of 16% failure for Group II.

T_2 = temperature in $^{\circ}$C of 16% failure for Group III.

NOTE:

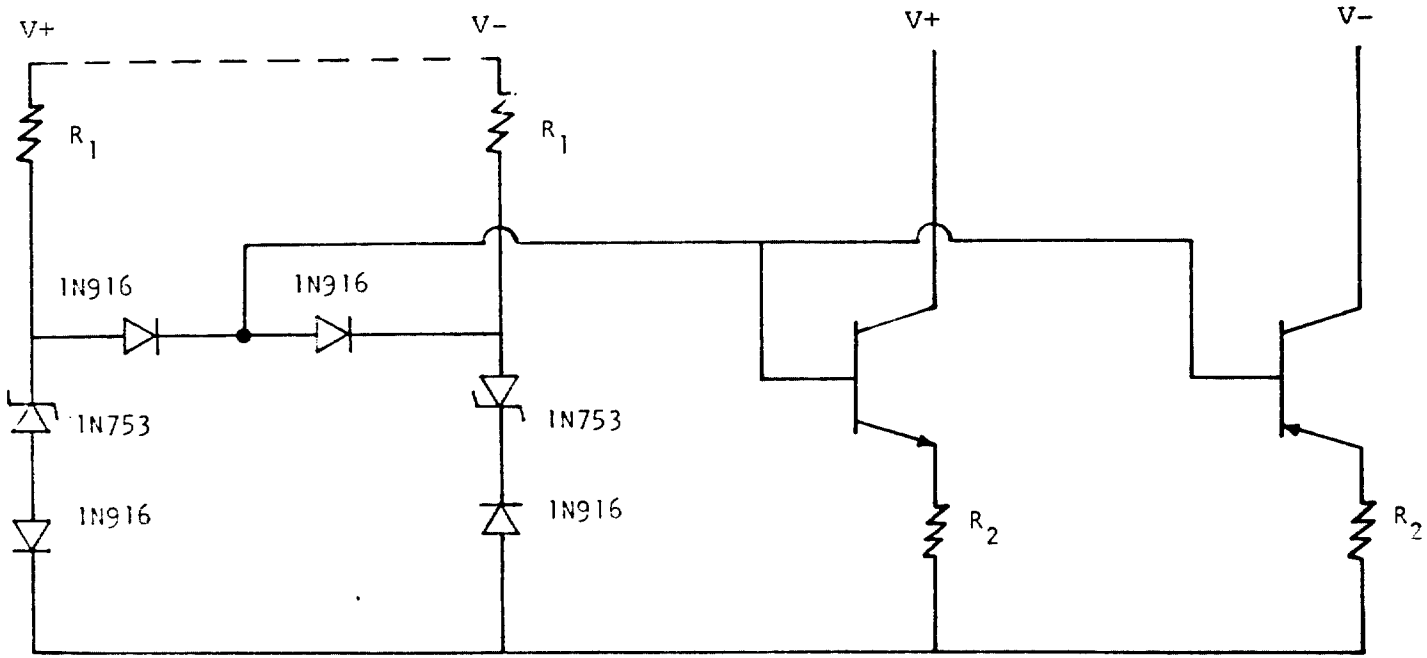
*Conditions for failure:

A) Open or short

B) Leakage exceeds the maximum limit by 100 times.

C) Other parameters exceed millimits by 50% or more.

TRANSISTORS



R_1 = 800 ± 5%, 2W

R_2 = Individual Part Type Calculation $R_2 = 5.2V/I_E$ ± 5%, R_2 = 113Ω ± 1%, 1/2W

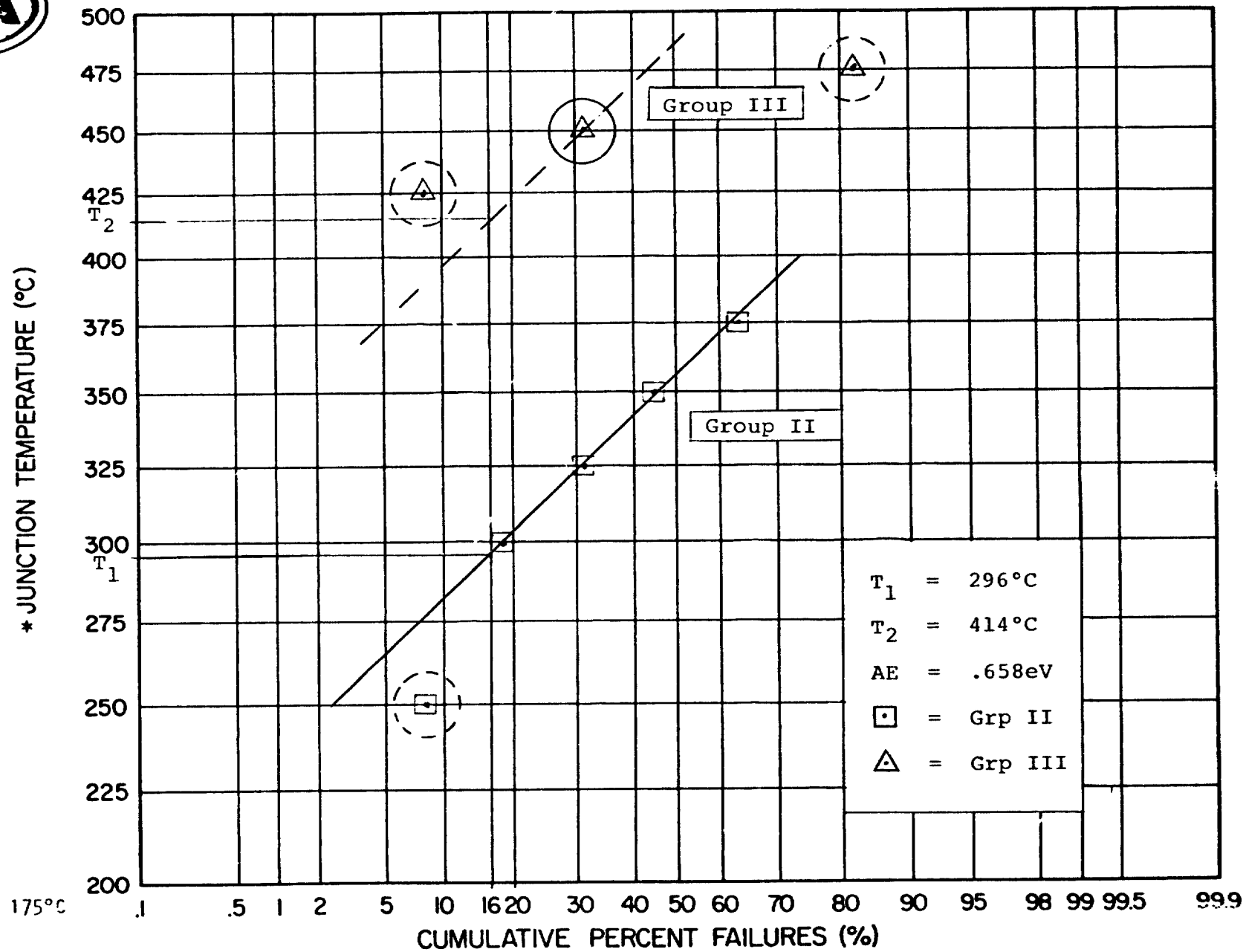
$P_d = V \cdot I_E$

V+ for NPN Transistors

V- for PNP Transistors

FIGURE 1

Power/Temperature Stress Circuit
for JANTX2N2219A



JANTX2N2219A

*NOTE

$T_J \approx T_A + 175°C$

FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, Texas Instruments

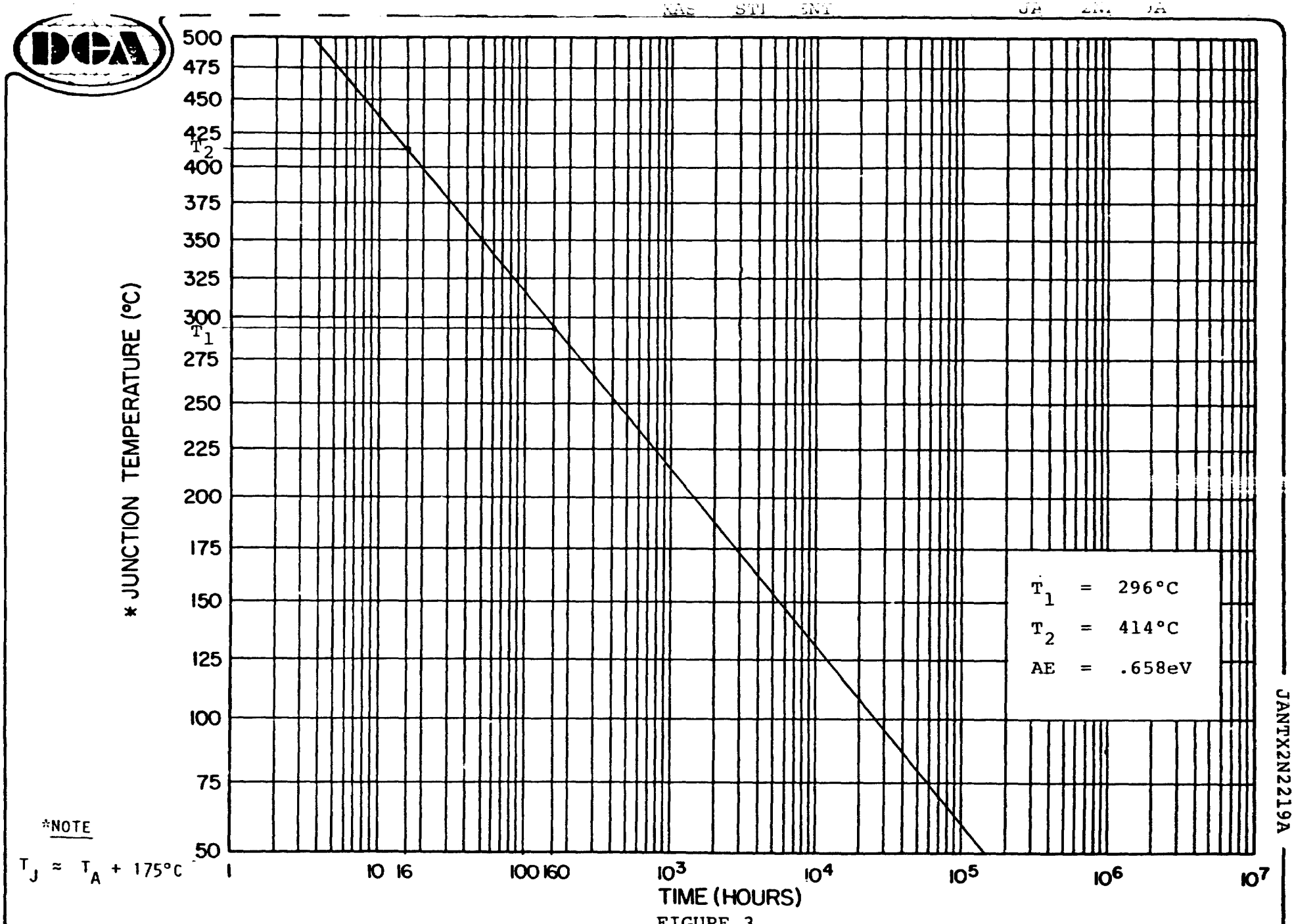
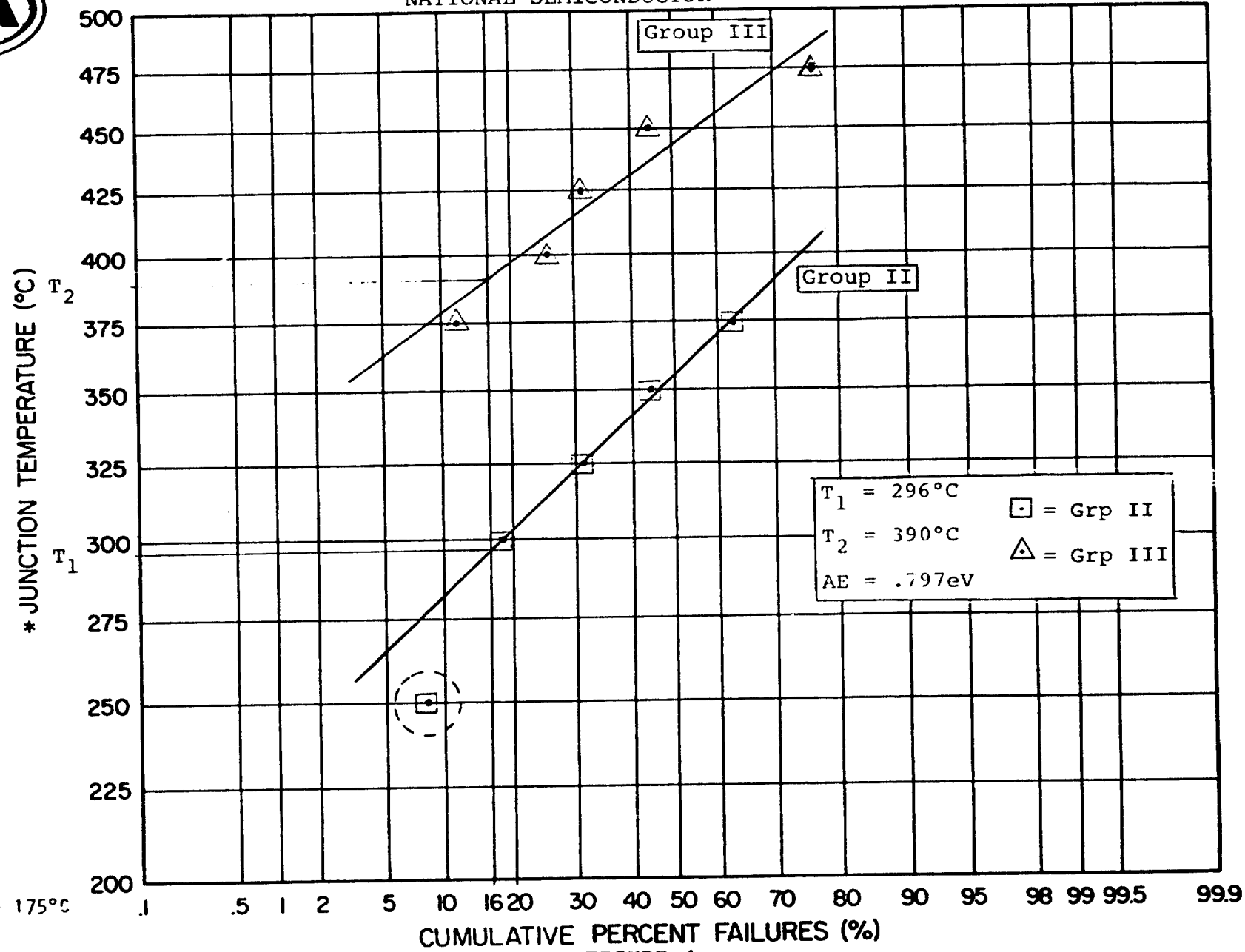


FIGURE 3
Time Steps Versus Junction Temperature, Texas Instruments

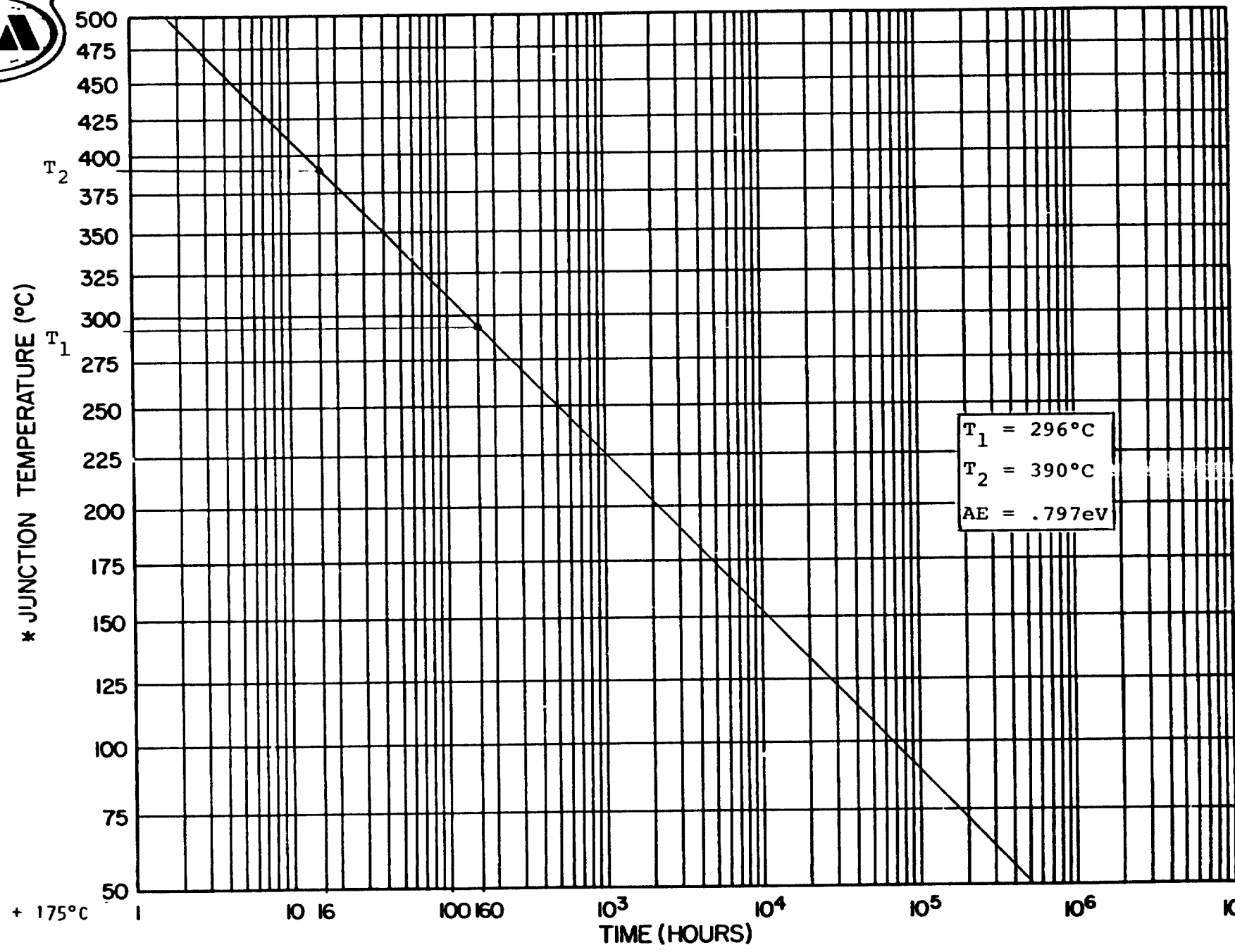


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, National Semiconductor



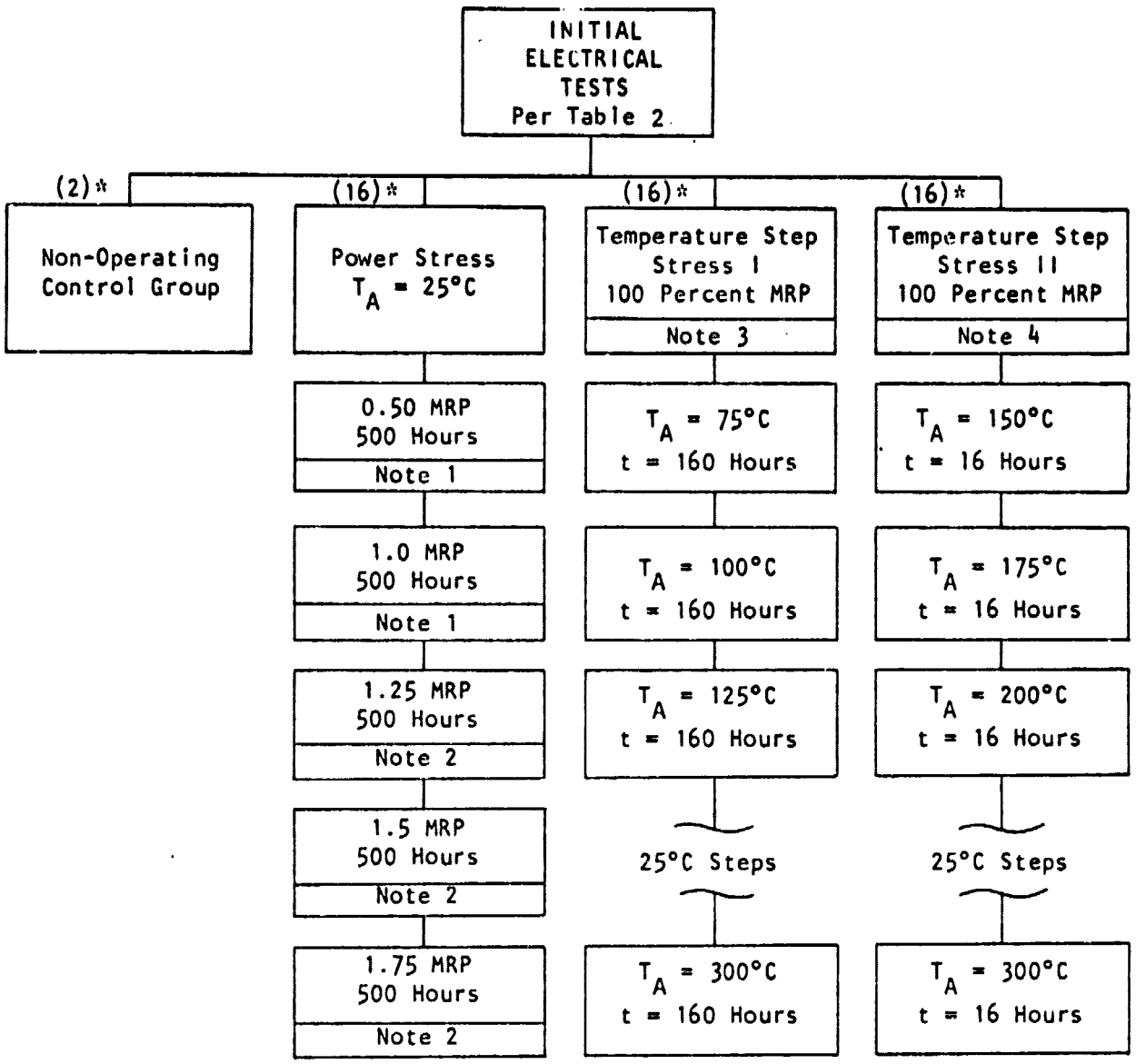
*NOTE

$T_J \approx T_A + 175°C$

FIGURE 5

Time Steps Versus Junction Temperature, National Semiconductor

TABLE 1
TEST FLOW DIAGRAM



*Quantity per manufacturer (Texas Instruments and National Semiconductor)

NOTES:

1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
3) Electrical measurements per Table 2 were made at the end of each 160 hours.
4) Electrical measurements per Table 2 were made at the end of each 16 hours.

TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_{CBO}	V_{CB} = 60V	-	10		1000	nA
h_{FE}	V_{CE} = 10V I_C = .1mA	50	900	25	1350	-
$V_{CE(SAT)1}$	I_C = 150mA I_B = 15mA		.3		.45	V
$V_{CE(SAT)2}$	I_C = 500mA I_B = 50mA		1.0		1.5	V

NOTES:
1/ In addition, any open or short shall be considered catastrophic.

TABLE 3
POWER STRESS BURN-IN CONDITIONS

I_E = 50 mA	
V_{CE}	Percent P_D
8V	50
16V	100
20V	125
24V	150
28V	175

NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of ±1% of the reading and ± one digit except for readings greater than 9.99mA which have an absolute accuracy of ±2% of the reading and ± one digit. The data also have a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.

TABLE 4
GROUP I – POWER STRESS DATA SUMMARY

PARAMETER	I_{CBO} = 10nA(MAX)		$V_{CE(SAT)1}$ = .3V(MAX)		$V_{CE(SAT)2}$ = 1.0V(MAX)		h_{FE} = 50(MIN) 900(MAX)	
CONDITIONS AND LIMIT	@ V_{CB} = 60V		@ I_C = 150nA I_B = 15mA		@ I_C = 500mA I_B = 50mA		@ V_{CE} = 10V I_C = .1mA	
IDENTIFICATION	TI	NS	TI	NS	TI	NS	TI	NS
INITIAL DATA								
MIN VALUE	60.00pA	650.0pA	105.0mV	123.0mV	272.0mV	121.0mV	89.80	146.0
MAX VALUE	910.0pA	2.810nA	140.0mV	151.0mV	386.0mV	358.0mV	245.0	293.0
MEAN	397.5pA	1.301nA	117.8mV	133.0mV	301.4mV	311.4mV	165.1	201.1
STD DEV	229.7pA	611.3pA	8.151mV	7.646mV	26.68mV	51.54mV	47.75	37.20
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 HRS	-6.300pA	-129.0pA	-2.700mV	-1.100mV	-1.800mV	8.700mV	.4000	-2.200
150 HRS	16.90pA	-37.00pA	6.600mV	1.700mV	28.50mV	17.60mV	.8000	.900
250 HRS	148.1pA	-110.0pA	-2.400mV	-1.200mV	-1.000mV	8.900mV	1.200	1.100
500 HRS	-87.50pA	-364.1pA	-3.300mV	-1.100mV	-3.900mV	9.300mV	.1000	-3.200
100% POWER								
550 HRS	-93.80pA	-260.0pA	10.30mV	.8000mV	52.10mV	15.50mV	8.000	4.900
650 HRS	-10.60pA	178.0pA	8.900mV	2.600mV	45.40mV	21.70mV	9.600	10.50
750 HRS	5.000pA	-18.00pA	2.300mV	.8000mV	25.00mV	15.20mV	11.70	14.50
1000 HRS	-42.50pA	-21.00pA	7.900mV	-.2000mV	22.50mV	13.10mV	11.60	13.50
125% POWER								
1010 HRS	-26.30pA	1.825nA	19.60mV	10.30mV	49.20mV	44.90mV	12.50	13.60
1025 HRS	-14.20pA	-223.0pA	-2.200mV	.9000mV	.9000mV	15.50mV	17.20	12.70
1050 HRS	4.500pA	-207.0pA	-1.200mV	1.000mV	7.000mV	16.50mV	17.30	16.00
1150 HRS	371.8pA	70.00pA	8.000mV	2.600mV	6.600mV	21.30mV	21.00	19.60
1250 HRS	-96.80pA	78.00pA	6.100mV	16.70mV	29.90mV	64.50mV	14.10	3.200
1500 HRS	-28.80pA	-114.0pA	-1.100mV	3.900mV	9.700mV	26.30mV	15.60	24.20

(continued on second sheet)

(continued from first sheet)

TABLE 4 (Cont'd)
GROUP I – POWER STRESS DATA SUMMARY

PARAMETER	I_{CBO} = 10nA (MAX)		$V_{CE(SAT)1}$ = .3V(MAX)		$V_{CE(SAT)2}$ = 1.0V(MAX)		h_{FE} = 50(MIN),900(MAX)	
CONDITIONS AND LIMITS	V_{CB} = 60V		I_C = 150mA I_B = 15mA		I_C = 500mA I_B = 50mA		V_{CE} = 10V I_C = .1mA	
IDENTIFICATION	TI	NS	TI	NS	TI	NS	TI	NS
INITIAL DATA								
MIN VALUE	60.00pA	650.0pA	105.0mV	123.0mV	272.0mV	121.0mV	89.80	146.0
MAX VALUE	910.0pA	2.810nA	140.0mV	151.0mV	386.0mV	358.0mV	245.0	293.0
MEAN	397.5pA	1.301nA	117.8mV	133.0mV	301.4mV	311.4mV	165.1	201.1
STD DEV	229.7pA	611.3pA	8.151mV	7.646mV	26.68mV	51.54mV	47.75	37.20
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 HRS	16.50pA	63.00pA	-1.500mV	3.800mV	6.200mV	25.90mV	17.70	7.500
1525 HRS	-78.20pA	-315.0pA	10.30mV	7.500mV	48.60mV	39.10mV	14.10	2.800
1550 HRS	9.800pA	-236.0pA	1.600mV	5.800mV	22.30mV	32.30mV	17.70	*-28.70
1650 HRS	-106.9pA	-389.4pA	.200mV	4.100mV	10.10mV	30.40mV	13.60	1.500
1750 HRS	15.80pA	-285.0pA	18.80mV	9.000mV	74.10mV	42.30mV	15.30	8.600
2000 HRS	-59.50pA	-250.0pA	25.90mV	10.50mV	74.50mV	46.30mV	14.80	*-38.60
175% POWER								
2010 HRS	79.90pA	*1.110mA	20.80mV	*2.200V	45.90mV	*2.183V	19.80	24.20
2025 HRS	353.2pA	JOB STOPPED	14.30mV	JOB STOPPED	72.00mV	JOB STOPPED	23.70	JOB STOPPED
2050 HRS	1.046nA	↓ ↓	11.30mV	↓ ↓	71.40mV	↓ ↓	22.30	↓ ↓
2150 HRS	206.1pA		14.50mV		86.70mV		18.90	
2250 HRS	22.50pA		19.10mV		83.10mV		20.50	
2500 HRS	*713.6uA		*750.5mV		*849.6mV		*81.20	
FINAL DATA								
MIN VALUE	40.00pA	690.0pA	115.0mV	134.0mV	303.0mV	330.0mV	132.0	1.600
MAX VALUE	9.990mA	9.990mA	9.990mV	9.990V	9.990V	9.990V	999.0	999.0
MEAN	713.6uA	1.110mA	868.3mV	2.333V	1.151V	2.494V	246.3	225.3
STD DEV	2.573mA	3.140mA	2.531	4.093V	2.460	4.007V	212.2	289.4

*NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT.

TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY

PARAMETERS	I_{CBO} = 10nA(MAX)		$V_{CE(SAT)1}$ = .3V(MAX)		$V_{CE(SAT)2}$ 1.0V(MAX)		h_{FE} = 50(MIN) 900(MAX)	
CONDITIONS AND LIMITS	V_{CB} = 60V		I_C = 150mA I_B = 15mA		I_C = 500mA I_B = 50mA		V_{CE} = 10V I_C = .1mA	
IDENTIFICATION	TI	NS	TI	NS	TI	NS	TI	NS
INITIAL DATA								
MIN VALUE	110.0pA	670.0pA	105.0mV	121.0mV	278.0mV	294.0mV	163.0	169.0
MAX VALUE	750.0pA	5.180nA	126.0mV	178.0mV	339.0mV	527.0mV	272.0	300.0
MEAN	444.4pA	1.686nA	115.1mV	144.3mV	300.3mV	359.9mV	210.5	214.6
STD DEV	181.1pA	1.128nA	4.484mV	16.14mV	13.33mV	52.55mV	30.99	39.22
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS / TEMP (T_A)								
160 / 75°C	67.90nA	73.00pA	18.30mV	11.50mV	43.60mV	24.90mV	46.90	-9.300
320 / 100°C	310.7nA	293.0pA	10.10mV	5.800mV	42.90mV	40.00mV	41.40	4.300
480 / 125°C	10.51nA	30.30nA	635.9mV	15.90mV	666.7mV	67.00mV	-35.20	-42.90
640 / 150°C	655.6pA	*771.5µA	847.2mV	82.60mV	866.7mV	300.2mV	-36.20	-8.300
800 / 175°C	*67.46µA	*676.2µA	20.40mV	23.90mV	71.30mV	82.30mV	26.70	70.80
960 / 200°C	*1.216mA	1.585nA	*1.988V	32.00mV	*1.975V	123.7mV	8.300	*106.1
1120 / 225°C	JOB STOPPED	JOB STOPPED	JOB STOPPED	JOB STOPPED	JOB STOPPED	JOB STOPPED	JOB STOPPED	JOB STOPPED
1280 / 250°C	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓ ↓
1440 / 275°C								
1600 / 300°C								
FINAL DATA								
FINAL TEMP (T_A)	200°C	200°C	200°C	200°C	200°C	200°C	200°C	200°C
MIN VALUE	70.00pA	890.0pA	111.0mV	149.0mV	287.0mV	380.0mV	1.600	3.300
MAX VALUE	9.990mA	11.30nA	9.990V	223.0mV	9.990V	708.0mV	999.0	221.0
MEAN	1.216mA	3.271nA	2.103V	176.3mV	2.275V	483.6mV	218.8	108.5
STD DEV	2.995mA	3.173nA	3.944V	26.19mV	3.858V	112.5mV	275.7	78.25

* NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT.

TABLE 6

GROUP TEMP STRESS DATA SUMMARY

PARAMETERS	I_{CBO} = 10nA(MAX)		$V_{CE(SAT)1}$ = .3V(MAX)		$V_{CE(SAT)2}$ = 1.0V(MAX)		h_{FE} = 50(MIN) 900(MAX)	
CONDITIONS AND LIMITS	V_{CB} = 60V		I_C = 150mA I_B = 15mA		I_C = 500mA I_B = 50mA		V_{CE} = 10V I_C = .1mA	
IDENTIFICATION	TI	NS	TI	NS	TI	NS	TI	NS
INITIAL DATA								
MIN VALUE	210.0pA	660.0pA	110.0mV	122.0mV	268.0mV	187.0mV	182.0	160.0
MAX VALUE	2.210nA	4.910nA	129.0mV	179.0mV	326.0mV	383.0mV	251.0	275.0
MEAN	610.6pA	1.442nA	116.9mV	142.1mV	290.0mV	331.8mV	217.4	226.7
STD DEV	445.0pA	995.5pA	5.487mV	11.73mV	16.06mV	20.62mV	19.54	33.40
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS TEMP (T_A)								
16 150°C	187.5pA	65.00pA	9.990mV	4.800mV	37.30mV	11.00mV	.1000	1.700
32 175°C	-149.3pA	-98.00pA	8.200mV	6.100mV	36.60mV	21.50mV	.2000	-4.800
48 200°C	1.375nA	45.43nA	20.70mV	8.200mV	114.1mV	37.70mV	3.800	-23.30
64 225°C	106.3pA	142.8nA	33.20mV	9.300mV	121.8mV	46.70mV	2.000	5.90
80 250°C	351.3pA	83.80nA	39.90mV	12.20mV	150.3mV	46.30mV	-7.000	41.20
96 275°C	66.52nA	183.0nA	*2.669V	936.9mV	*2.687V	*1.044V	*-71.80	*-24.80
112 300°C	*599.0nA	384.9nA	*6.943V	*3.328V	*6.881V	*3.393V	*-77.90	*205.3
FINAL DATA								
FINAL TEMP (T_A)	300°C	300°C	300°C	300°C	300°C	300°C	300°C	300°C
MIN VALUE	390.0pA	130.0pA	130.0mV	153.0mV	334.0mV	367.0mV	0.000	1.400
MAX VALUE	999.0nA	999.0nA	9.990V	9.990V	9.990V	9.990V	999.0	999.0
MEAN	599.6nA	386.3nA	7.060V	3.470V	7.171V	3.725V	139.5	432.0
STD DEV	489.1nA	444.8nA	4.476V	4.611V	4.309V	4.443	296.8	413.2

*NOTE: CATASTROPHIC REJECT(S) REMOVED FROM DATA AFTER THIS POINT.

TABLE 7
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		UNITS	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	MIN	MAX			TI	NS	TI	NS	TI	NS
I_{CBO}	-	.01	μA		*+27.446	*+50.455	*+213.97	*+241.29	+.09534	+.11999
$V_{CE(SAT)1}$	-	.3	V		*+.03625	*+.10356	*+.58665	+.02862	*+1.3891	*+.61507
$V_{CE(SAT)2}$	-	1.0	V		*+.06594	*+.12265	*+.61103	+.10635	*+1.4326	*+.65717
h_{FE}	50	900	-		*+16.181	*+4.8500	*+8.6500	*-15.250	*-21.514	*+28.743

*NOTE: Catastrophic reject(s) removed from data after this point.

TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY JAN TX2N2219A

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
100% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
125% 10 hr.	0	–	0	–
15 hr.	1	A	1	A
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
150% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	3	A
100 hr.	0	–	1	A
100 hr.	0	–	0	–
250 hr.	0	–	3	A
175% 10 hr.	0	–	1 \ 2	A \ E
15 hr.	0	–	JOB STOPPED	
25 hr.	0	–	↓	↓
100 hr.	0	–	↓	↓
100 hr.	0	–	↓	↓
250 hr.	1	D	↓	↓

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	1	B	1	A
100° C	0	–	0	–
125 °C	1 \ 1	A \ C	2	A
150 °C	1 \ 1	B \ E	1 \ 1	D \ F
175 °C	1 \ 1	B \ A	2	A
200 °C	1 \ 2	B \ E	3	A
225 °C	JOB STOPPED		JOB STOPPED	
250 °C	↓	↓	↓	↓
275 °C	↓	↓	↓	↓
300 °C	↓	↓	↓	↓

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150 °C	0	–	0	–
175 °C	0	–	0	–
200 °C	0	–	2	A
225 °C	0	–	2	B
250 °C	1	A	1	B
275 °C	3 \ 1	E \ G	1 \ 1	G \ D
300 °C	2 \ 5 \ 1	G \ B	1 \ 2	B \ D A \ E

MFR "A" - Texas Instruments

MFR "B" - National Semiconductor

NOTES:

A - $h_{FE} < 25$

B - $I_{CBO} > 1mA$

C - $V_{CE(SAT)1} > .45V$ and $V_{CE(SAT)2} > 1.5V$

D - See Notes B and C

E - See Notes A and C

F - See Notes A and B

G - See Notes A, B and C

TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY JAN TX2N2219A

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
100% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
125% 10 hr.	1	A	1	C
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
150% 10 hr.	0	–	0	–
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	1	D
250 hr.	1	A	0	–
175% 10 hr.	1	B	0	–
15 hr.	0	–	JOB STOPPED	
25 hr.	0	–	↓	↓
100 hr.	0	–	↓	↓
100 hr.	0	–	↓	↓
250 hr.	0	–	↓	↓

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	–	0	–
100° C	0	–	0	–
125°C	1	C	0	–
150°C	1	A	1	A
175°C	1	C	0	–
200°C	0	–	1	C
225°C	JOB STOPPED		JOB STOPPED	
250°C	↓	↓	↓	↓
275°C	↓	↓	↓	↓
300°C	↓	↓	↓	↓

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	–	0	–
175°C	0	–	0	–
200°C	1	C	0	–
225°C	0	–	0	–
250°C	0	–	0	–
275°C	1	A	1 \ 2	C \ D
300°C	1	E	3	C

MFR "A" - Texas Instruments

MFR "B" - National Semiconductor

NOTES:

A - $V_{CE(SAT)1}$ limit failure

B - S/N 4603 removed from testing as MIL-S-19500 failure

C - I_{CBO} limit failure

D - h_{FE} minimum limit failure

E - S/N 4633 visual reject due to handling

APPENDIX

FAILURE ANALYSIS

FAILURE ANALYSIS

Date 19 May 1978

J/N 2CN242-01B **P/N** 2N2219A (NPN) **MFR** Texas Instruments

FAILURE VERIFICATION:

S/N	BV_{CEO} -volts- Lim - 10 nA	BV_{CEO} -volts-	I_{CBO} -μA- @V_{CB} = 60 V.	BV_{EBO} -volts-	h_{FE} @I_C = 100μA; V_{CE}=10 V. Min - 50	V_{BEO} -volts- @I_{BEO}= 10mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
621	40 snap	100	5 nA	6.5(R)	16(R)	0.81	07 (125°C)	CAT
622	42H	110	9 nA	6.6(R)	24(R)	0.75	11 (175°C)	CAT
4627	52 Inv	120	162 nA	6.4(R)	20(R)	0.81	03 (75°C)	CAT

INTERNAL VISUAL INSPECTION:

All the T.I. samples have clumps of silicon material scattered over the dice due to condensation of silicon vaporized during laser scribing. Purple plague is also present on all dice. S/N 4627 has a partly melted internal emitter wire (see Figure A-3).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

FAILURE ANALYSIS

Date 19 May 1978

J/N 2CN242-01B **P/N** 2N2219A (NPN) **MFR** National Semiconductor

FAILURE VERIFICATION:

S/N	BV_{CEO} - volts	BV_{CBO} -volts-	I_{CBO} -μA- @ V_{CB} = 60 V. (Max = 10 nA)	BV_{EBO} -volts-	h_{FE} @I_C=100μA; V_{CE} = 10 V. (Min = 50)	V_{BEO} -volts- @I_{BEO} = 10 mA	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
4671	130	130	<1 nA	7.6(R)	10(R)	0.72	13 (200°C)	CAT
4673	132	132	<1 nA	7.8(R)	7 (R)	0.73	03 (75°C)	CAT
4677	shorted	shorted	shorted	shorted	--	0.03	09 (150°C)	CAT

INTERNAL VISUAL INSPECTION:

All samples have AuAl2 ("purple plague") surrounding the gold ball bonds.

S/N 4673 has a smear which dragged over the E-B junction causing some oxided cracking (see Figure A-2).

S/N 4677 exhibits a well formed E-B short due to electromigration of gold. The emitter wire is partly melted but still is connected (see Figure A-3).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

CONCLUSIONS

While National parts had no consistent failure modes, the Texas Instrument parts give evidence of some surface contamination. Specific causes of failure are as follows:

National Semiconductor

S/N 4671 and S/N 4673 have partially shorted base-emitter junctions which appear to be caused by mechanical damage to the junctions (see Figure A-2).

S/N 4677 has a shorted base-emitter junction due to electromigration of gold (see Figure A-3). The emitter metal reached at least 577°C.

Texas Instruments

For S/N 4621 and 4622, some residual surface contamination could be seen in the voltage "snap", hysteresis, and inversion of BV_{CEO} on the curve tracer. In the case of S/N 4627, the leakage due to surface inversion exceeded the I_{CBO} limit and resulted in failure. (See "Failure Verification" data above.)

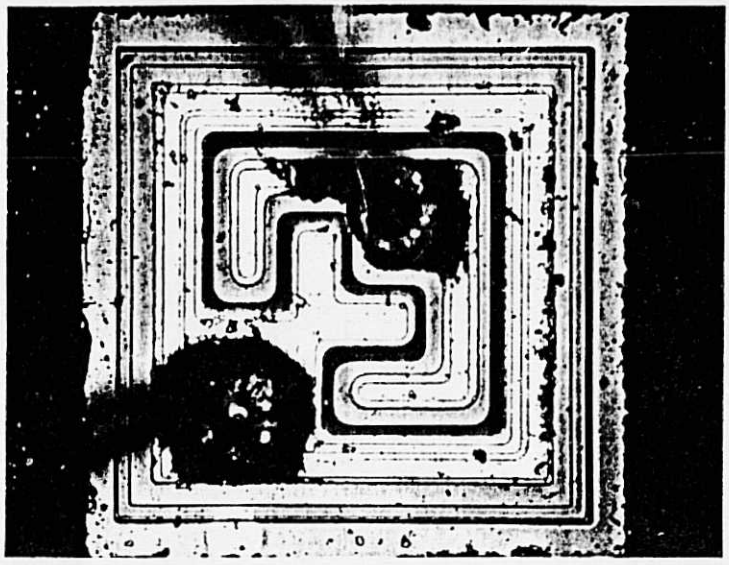


FIGURE A-1
S/N 4627, Texas Instruments, 160X.
Typical Texas Instruments' die showing "purple plague" formation and condensed silicon vapor deposits.

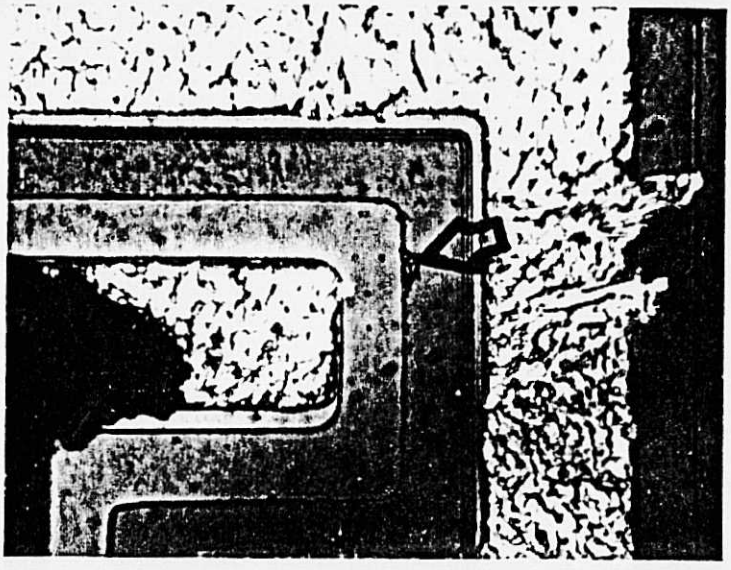


FIGURE A-2
S/N 4673, National Semiconductor, 800X.
Arrow indicates mechanical damage on emitter-base junction.

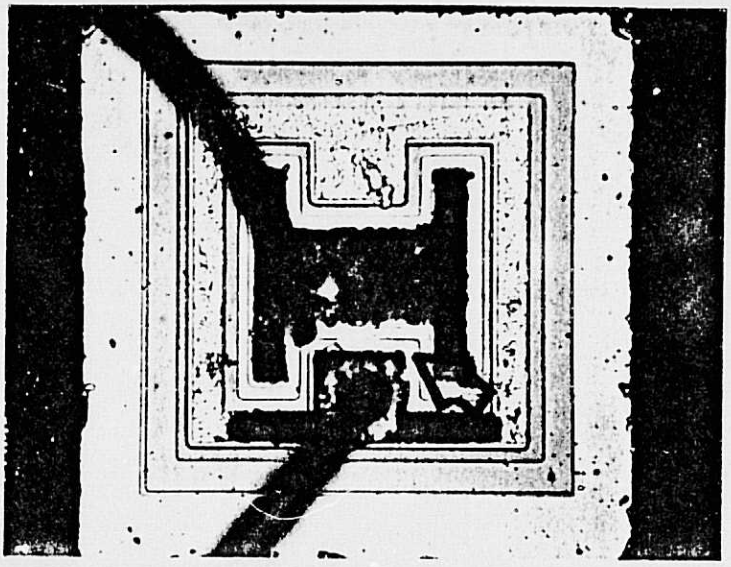


FIGURE A-3
S/N 4677, National Semiconductor, 160X.
Arrow indicates emitter-base
short due to gold migration.